(12) UK Patent Application (19) GB (11) 2 219 414 (13) A

(43) Date of A publication 06.12.1989

(21) Application No 8914729.2

(22) Date of filing 12.06.1987

Date lodged 27.06.1989

(30) Priority data
(31) 8614286 (32) 12.06.1986 (33) GB

(62) Derived from Application No 8713829.3 under Section 15(4) of the Patents Act 1977

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(51) INT CL[4]
G02B 6/30

(52) UK CL (Edition J)
G2J JGDB

(56) Documents cited
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(58) Field of search
UK CL (Edition J) G2J JGDB JGEA
INT CL[4] G02B

(54) Alignment of optical fibres with integrated optical device

(57) An array of optical fibres (in region 8) is connected to an array of parallel optical waveguides 3 in an integrated optical device 1, each fibre being placed along a V-groove 6 in a silicon wafer 5, and channels 11 etched into the substrate of the integrated optical device 1 co-operate with the ridges 10 between the V-grooves to enable the fibres to be aligned passively, in the transverse direction, with the waveguides. The ridges 10 project axially beyond the ends of the optical fibres.

The optical fibre may have a flat in its cross-section and be clamped between two opposed parallel surfaces of a connector, one surface receiving the fibre and the other surface being flat and engaging the flat of the fibre.

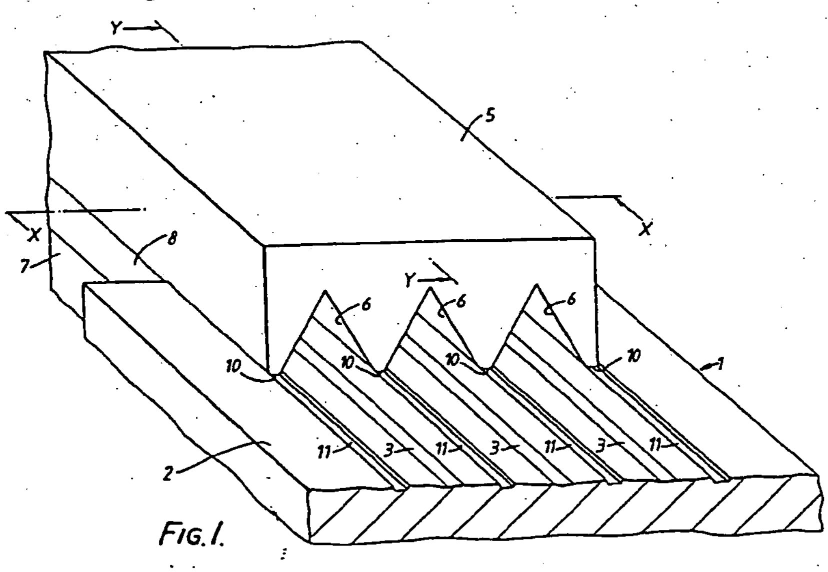

FIG. 1.

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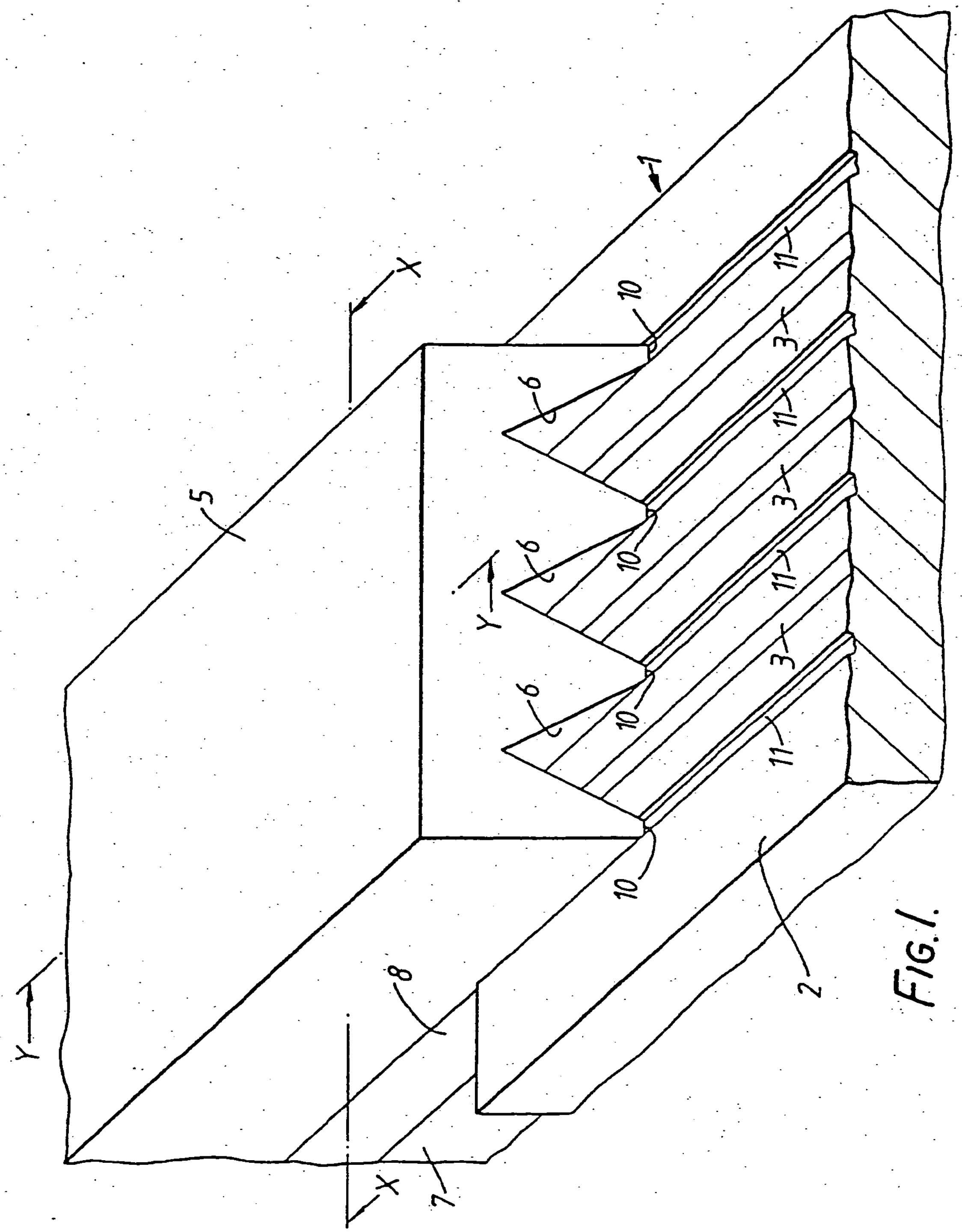

FIG. 1.

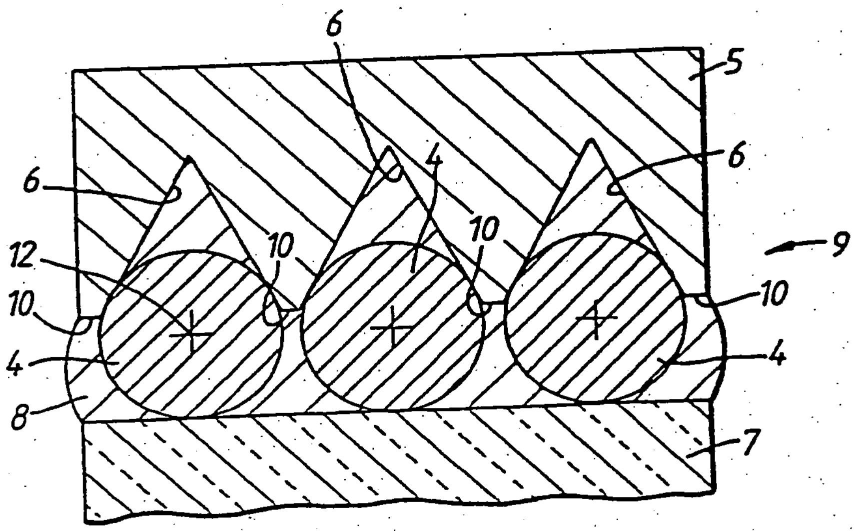

FIG. 2.

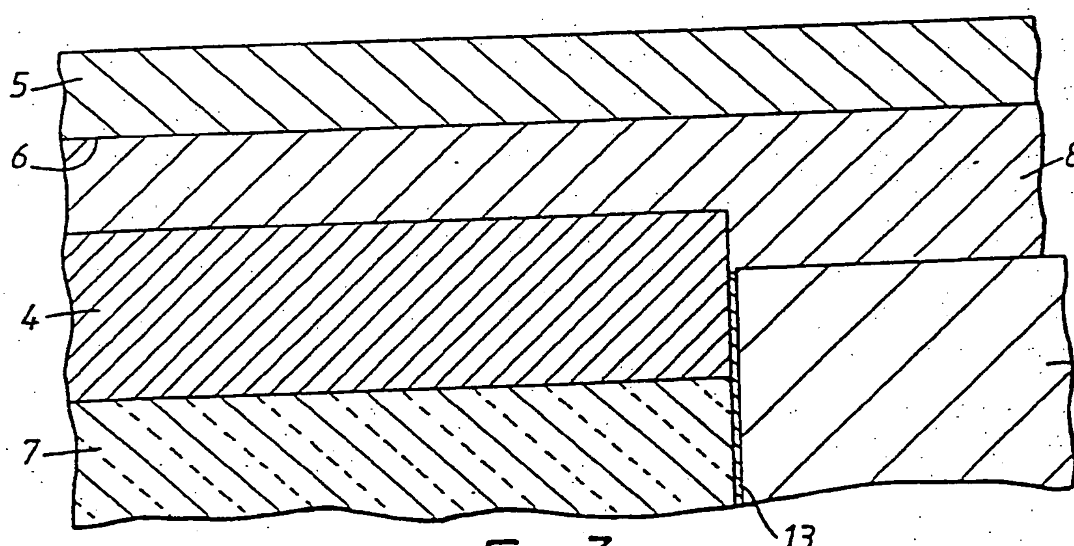

FIG. 3.

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Alignment of Optical Fibres with Integrated Optical Device

This invention relates to means for aligning an array of optical fibres with an array of optical waveguides in an integrated optic device.

It is particularly suitable for use with monomode fibres in which the energy travels in a very small region on the axis, requiring high precision in the radial alignment of the fibres with their respective waveguides. Tolerances of 1 or 2 μm are typical.

It is well known to etch a number of spaced apart, parallel, V-shaped grooves into a wafer such as silicon, and then to place an optical fibre along each groove. The fibre may be held in place between the groove, and either a complementary groove in a second silicon wafer or a flat surface by using an adhesive. Thus the lateral spacing of a plurality of fibres may be determined by fixing each fibre in one of a number of parallel grooves in the silicon wafer. The end of the optical array so formed is ground and polished so that the ends of the fibres, the end face of the silicon wafer, and the end face of the second wafer or the flat surface, will all lie in one plane.

When it is desired to form an optical interface between the array of fibres, and an array of a corresponding plurality of waveguides in an integrated

optical device, the end of the optical array is caused to abut the end face of the integrated optical device. The lateral spacing of the optical fibres, which is determined by the frequency of the grooves, corresponds to the lateral spacing of the waveguides in the integrated optical device. The optical array must then be aligned in the two degrees of freedom normal to the axes of the fibres, that is, the array must be aligned vertically and transversely. This is done by causing light of a known intensity to travel along a fibre and a respective waveguide. The intensity of the light being emitted from the waveguide is measured using a sensor, and the intensity of this emitted light is maximised by moving the optical array with respect to the integrated optical device in the two degrees of freedom. This procedure is known as active alignment.

In another known method of aligning an array of fibres with a plurality of waveguides in an integrated optical device, the end face of the silicon wafer does not lie in the same plane as the ends of the fibres and end face of the second wafer or flat surface, but instead it projects beyond that plane. The portion of the wafer which projects beyond the ends of the fibres and end face of the second wafer or flat surface, is caused to overlap the integrated optical device when the ends of the fibres abut the end face of the integrated optical device and so fixes the height of the fibres relative to the integrated

optical device. Thus the height of the fibres relative to the waveguides in the integrated optical device is determined by the dimensions of the V grooves. The array of fibres is then actively aligned, as described above.

A problem with these known methods of aligning an array of fibres with a plurality of waveguides, is that it is necessary to use active alignment methods for at least part of the alignment procedure. Active alignment methods are labour-intensive and time-consuming and often expensive. They do not lend themselves to automation.

The invention seeks to provide an improved alignment apparatus for aligning an array of optical fibres with an array of optical waveguides in an integrated optical device.

The invention provides means for interconnecting an array of optical fibres with a corresponding array of parallel optical wave guides, comprising a connector for clamping the ends of the fibres precisely parallel to each other, and an integrated optical device in which the wave guides are formed, the device having formations extending parallel to the waveguides, the connector having a portion projecting axially from the fibre ends in use and having axially-extending formations, and the connector being connectable to the integrated optical device such that the projecting portion overlaps the device and the formations thereon mate with the formations on the device to guide

the fibres into precise transverse alignment with the waveguides.

Where the fibre array and the waveguide array are planar, their vertical alignment (normal to their planes) may be ensured by clamping the fibres at an appropriate height relative to the surface of the connector and the integrated optical device which engage when interconnected, as described above in relation to known methods. The advantage of the invention is that transverse alignment be achieved passively, i.e. without any active techniques of the type described above, with a high degree of precision by the mating of the said axially-extending formations on the connector and the integrated optical device.

Preferably, the formations in the connector are grooves spaced by ridges. These grooves and ridges are preferably continued within the connector and constitute means for the clamping of the fibre ends.

Preferably, the formations on the integrated optical device are channels formed in a planar surface thereof.

The invention also relates to a connector for clamping rotationally asymmetric optical fibres. Optical fibres which are asymmetric and thus polarisation sensitive are usually required to be clamped with their ends at a predetermined angular position.

Accordingly, the invention in a further aspect provides an assembly comprising an optical fibre having a

flat in its cross-section, clamped between two opposed parallel surfaces of a connector, one of the surfaces having a recess receiving the fibre and the other surface being flat and engaging parallelly the said flat of the fibre. This ensures that the fibre is at the correct angular orientation since there is a unique position at which its flat is parallel to the clamping surfaces.

Preferably, the recess is a groove which also positions the fibre radially.

The invention also provides a method of clamping an optical fibre having a flat in its cross-section between two opposed parallel surfaces of a connector, a first of the surfaces having a recess for receiving the fibre and the second surface being flat, comprising placing the fibre partially in the recess with its flat approximately parallel to the first surface and outside the recess, moving the second surface normally thereof into engagement with the flat of the fibre, and securing the first and second surfaces together so that the fibre rotates to adopt an orientation with its flat parallel to both the surfaces.

Preferably, the fibre section is circular other than at the flat, so that the said rotation is facilitated.

The invention is each of its aspects will now be illustrated by way of example, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of apparatus embodying the first aspect of the invention,

Figure 2 is a transverse cross-section along X-X of Figure 1 and

Figure 3 is a longitudinal cross-section along Y-Y of Figure 1.

Referring to the drawings, an integrated optical device 1 comprises a substrate 2 made of lithium niobate and optical waveguides 3 formed by diffusing titanium into the titanium niobate. Optical fibres 4 are held in position between a silicon wafer 5, which has been etched to form V grooves 6, and a flat backing plate 7 made from glass. The space around each fibre 4 is filled with a compound 8 such as wax or solder, which may be softened. The end face of the resulting connector 9 formed from the wafer 5, fibres 4, backing plate 7 and compound 8 is optically polished. The connector 9 is then heated on a jig to soften the compound 8, and the silicon wafer 5 is moved forwards a distance of approximately 1mm. The connector 9 may then be secured with a high temperature epoxy resin.

Shallow channels 11 are formed photolithographically in the integrated optical device 1, and are etched into the substrate 2. The channels 11 are approximately 1-2 μm deep, and the exact profile of each channel is unimportant, although the base should be substantially flat. Ridges 10 between the grooves 6 are located in the

channels 11, and the connector 9 is held in position such that the ends of the fibres 4 and the end of the backing plate 7 abut the end face of the integrated optical device 1. Contact may be maintained between the connector 9 and device 1 by the application of a compressive force and so no adhesive is required to hold the connector 9 and device 1 together. It is therefore possible to insert a refractive index-matching material 13 between the fibre ends and the waveguide ends.

The frequency and position of the ridges 10 and the channels 11 are such that when the ridges 10 are located in the channels 11 the fibres 3 are aligned with the waveguides 2. Vertical alignment of the fibres is achieved by etching the grooves 5 to the correct dimensions such that, when the ridges 10 are located in the channels 11, the position of maximum intensity, known as the mode centre 12, of each fibre 3 is aligned with the mode centre of the respective waveguide 2 in order to achieve maximum transmission. The height of the fibres may be further adjusted by altering the depth of the channels 11.

It will be appreciated that the grooves 6 and channels 11, extending axially, permit relative axial sliding movement of the connector and the device 1 even when they are engaged in mating relationship, to allow the exposed end faces of the fibres 4 and waveguides 3 to be

brought into abutting relationship.

In an alternative embodiment, the space around each fibre 4 is not filled with the compound 8, and the connector 9 is held together by compressive forces. The wafer 5 is caused to move forward by momentarily releasing the forces, allowing the wafer 5 to move, resulting in wafer 5 extending beyond the ends of the fibres and the end face of plate 7.

The channels 11 in the integrated optical device may, instead of being formed by etching, be formed by depositing a dielectric or metallic material on the substrate 2, in such a way that the area not covered by the material takes the form of channels. A 3 μm layer of polyimide could be deposited and selectively etched.

Also, the wafer 5 could instead be of silica, the grooves 6 being machined by laser or otherwise.

The fibres could be cleaved before the connector is assembled, to provide an accurate orthogonal end face, avoiding the need for the optical polishing of the assembly comprising the wafer, fibres and backing plate.

Also, the height of the fibres relative to the waveguides may be altered by depositing a dielectric or metallic material on to the ridges 10, thus effectively making the grooves deeper.

The apparatus is particularly suitable for use with polarisation-holding fibres which are substantially "D" shaped in cross-section, i.e. cylindrical with a segment

removed. The fibres may be positioned such that the flat side of each fibre is in contact with the flat backing plate. The fibres will then all be positioned at the same angular orientation.

The fibres are clamped in the connector by placing the fibres partially in the grooves 6 with their flats approximately parallel to the wafer plane and outside the grooves 6, moving the backing plate 2 normally into engagement with the flats (or, initially, with the edges of the flats furthest from the wafer 5), and securing the wafer 5 and plate 2 together. The fibres rotate to adopt the unique orientation with the flats parallel, as the opposed clamping surfaces are brought normally together.

CLAIMS

1. Means for interconnecting an array of optical fibres with a corresponding array of parallel optical wave-guides, comprising a connector for clamping the ends of the fibres precisely parallel to each other, and an integrated optical device in which the waveguides are formed, the device having formations extending parallel to the waveguides, the connector having a portion projecting axially from the fibre ends in use and having axially-extending formations, and the connector being connectable to the integrated optical device such that the projecting portion overlaps the device and the formations thereon mate with the formations on the device to guide the fibres into precise transverse alignment with the waveguides.

2. Interconnecting means according to claim 1, wherein the formations in the connector are grooves spaced by ridges.

3. Interconnecting means according to claim 2, wherein the grooves and ridges are continued within the connector and constitute means for the clamping of the fibre ends.

4. Interconnecting means according to claim 3, wherein the grooves are made in a planar surface of a first connector body and the connector comprises a second connector body having a surface which, in use, clamps the fibre ends firmly into their respective grooves.

5. Interconnecting means according to any preceding claim, wherein the formations on the integrated optical

device are channels formed in a planar surface thereof.

6. Interconnecting means according to claim 5, wherein the wave-guides are formed in the said planar surface, spaced transversely from the channels.

7. Interconnecting means according to claim 6, wherein the wave-guides and the channels alternate in the transverse direction.

8. Interconnecting means according to claim 5, 6 or 7, wherein the depths of the grooves and the channels are such, in relation to the vertical positions of the waveguides and the diameters of the fibres, that the waveguides and the fibres are placed in vertical alignment as well as transverse alignment when the connector is connected to the integrated optical device.

9. Interconnecting means according to any preceding claim, further comprising an array of optical fibres clamped in the connector.

10. Interconnecting means according to any preceding claim, wherein the said formations on the connector and the integrated optical device when in their mating relationship still permit relative axial movement of the connector and the device to allow the exposed end faces of the fibres and the waveguides to be slid into abutting relationship.

11. Interconnecting means according to any preceding claim, wherein the said optical fibres are monomode

fibres.

12. Interconnecting means substantially as described herein with reference to the accompanying drawings.

13. An assembly comprising an optical fibre having a flat in its cross-section, clamped between two opposed parallel surfaces of a connector, one of the surfaces having a recess receiving the fibre and the other surface being flat and engaging parallely the said flat of the fibre.

14. An assembly according to claim 13, wherein the recess is a groove which also positions the fibre radially.

15. An assembly according to claim 13 or 14, comprising at least one further optical fibre also having a flat in its cross-section, and also clamped between the said parallel surfaces, the said one surface having a recess for each of the fibres, such that the flats of all the fibres are parallel.

16. A method of clamping an optical fibre having a flat in its cross-section between two opposed parallel surfaces of a connector, a first of the surfaces having a recess for receiving the fibre and the second surface being flat, comprising placing the fibre partially in the recess with its flat approximately parallel to the first surface and outside the recess, moving the second surface normally thereof into engagement with the flat of the fibre, and securing the first and second surfaces together so that

the fibre rotates to adopt an orientation with its flat parallel to both surfaces.

17. A method according to claim 16, wherein the fibre section is circular other than at the flat.

Amendments to the claims have been filed as follows

1. An assembly comprising an optical fibre having a flat in its cross-section, clamped between two opposed parallel surfaces of a connector, one of the surfaces having a recess receiving the fibre and the other surface being flat and engaging parallely the said flat of the fibre.

2. An assembly according to claim 1, wherein the recess is a groove which also positions the fibre radially.

3. An assembly according to claim 1 or 2, comprising at least one further optical fibre also having a flat in its cross-section, and also clamped between the said parallel surfaces, the said one surface having a recess for each of the fibres, such that the flats of all the fibres are parallel.

4. A method of clamping an optical fibre having a flat in its cross-section between two opposed parallel surfaces of a connector, a first of the surfaces having a recess for receiving the fibre and the second surface being flat, comprising placing the fibre partially in the recess with its flat approximately parallel to the first surface and outside the recess, moving the second surface normally thereof into engagement with the flat of the fibre, and securing the first and second surfaces together so that the fibre rotates to adopt an orientation with its flat parallel to both surfaces.

5. A method according to claim 4, wherein the fibre section is circular other than at the flat.

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